OBSERVATIONS ON FOREST TREE RUSTS

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The undertaking of the checking by cultural methods of various forest-tree rusts occurring in the Northwest has established several host relationships previously held doubtful. The recent works of Fraser[1] and Ludwig[2] have aided in the clearing of some of the problems concerned. Fraser's results with species of Uredinopsis on ferns and the final conclusion to the effect that the five species of Uredinopsis used in his experiments have their aecial stage on *Abies balsamea* is an important contribution toward a clearer understanding of the interesting group of rusts occurring on ferns. The five species with which Fraser worked are *Uredinopsis struthiopteridis* Störmer, *U. osmundae* Magn., *U. atkinsonii* Magn., *U. mirabilis* Magn., and *U. phegopteridis* Arth., and a study of the microscopical characters reveals no great differences between them. Fraser[3] in his last article came to the conclusion that all of the five species with which he had been working were identical with the exception of *U. mirabilis* and considered this one different on account of the fact that positive results with aeciospores from *Abies balsamea* were secured on *Onoclea sensibilis* only. In a recent communication received from Fraser, March 27, 1916, he states that Arthur examined all the field collections of *Peridermium balsameum* Pk. and cultures and came to the conclusion that there are no morphological differences in the aecial stages produced on *Abies balsamea* by inoculations of the five species of Uredinopsis. A close comparison of the spore measurements and lengths of beaks of the five species as published by Arthur[4] show no great differences in size from what might be expected as a result of the influences of the various

[1] Fraser, W. P. (*a*) Cultures of Heteroecious Rusts. Mycologia, **4**: 175. 1912.
(*b*) Further Cultures of Heteroecious Rusts. Mycologia, **5**: 233. 1913.
(*c*) Notes on *Uredinopsis mirabilis* and Other Rusts. Mycologia **6**: 25. 1914.

[2] Ludwig, C. A. Notes on Some North American Rusts with Caeoma-like Sori. Phytopathology **5**: 273, 1915.

[3] Fraser, W. P. Notes on *Uredinopsis mirabilis* and Other Rusts. Mycologia **6**: 25. 1914.

[4] Arthur, J. S. Uredinales. N. Amer. Flora **7**: 115. 1907.

fern hosts. The variations in the spore markings are negligible. In view of the results secured by Fraser and the determinations by Arthur, it is suggested that these five species be combined under the name of one species of Uredinopsis. The aecial stages of all five species have been found to be identical with *Peridermium balsameum* and the close similarity of *P. pseudo-balsameum* (D. & H.) Arth. with *P. balsameum* has led us to consider them here as one species, namely, *Peridermium balsameum*. The differences in the description of the two species do not seem to be of sufficient importance to continue their separation. The description given by Arthur and Kern[5] give a slightly larger spore for *P. balsameum* and no mention is made of the color of the spores of *P. pseudo-balsameum* which are colorless as in the other species. The peridia of both are fairly long (0.75–1 mm.) and with the colorless spores furnish excellent means of identification. All stages of this rust should therefore be referred to one species of Uredinopsis. The aecial stage was not only found in abundance this season on *Abies grandis* but also on *A. lasiocarpa*. This fungus has been collected in the Northwest in 1896 under the name of *P. pseudo-balsameum* (D. & H.) Arth. Hedgcock[6] reports *P. pseudo-balsameum* on *Abies grandis*, *A. lasiocarpa*, and *A. nobilis* in 1912. In a recent article by Schmitz[7] a claim is made to the first collection of the fungus west of the Mississippi Valley. A glance at the literature[8] will show that *Peridermium balsameum* was collected on *Abies grandis* on the slope of Mt. Paddo, Wash., by W. N. Suksdorf in October, 1903. *P. balsameum* was collected on *Abies grandis* in California in 1896. Many other collections of this fungus have been made since then and the collections of this laboratory at Missoula show considerable material (eight collections) from the northwestern states collected during the years 1911 to 1916.

Uredinopsis pteridis

During the past two seasons a very interesting Peridermium has been collected on the needles of *Abies grandis* (fig. 1). This fungus is

[5] Arthur, J. C., and Kern, F. D. Uredinales. N. Amer. Flora **7**: 115. 1907.

[6] Hedgcock, G. G. Notes on Some Western Uredineae Which Attack Forest Trees. Mycologia **4**: 141. 1912.

[7] Schmitz, H. · Preliminary Note on the Occurrence of *Peridermium balsameum* in Washington. Phytopathology **6**: 369. 1916.

[8] Arthur, J. C., and Kern, F. D. North American Species of Peridermium. Bull. Torrey Club **33**: 403. 1906.

conspicuous by its appearance on the second year needles of its host, by its white aeciospores and unusually long peridia. Most of the other needle rusts occurring on conifers occupy the needles of the season and this fact is accounted for by the overwintering of the telial

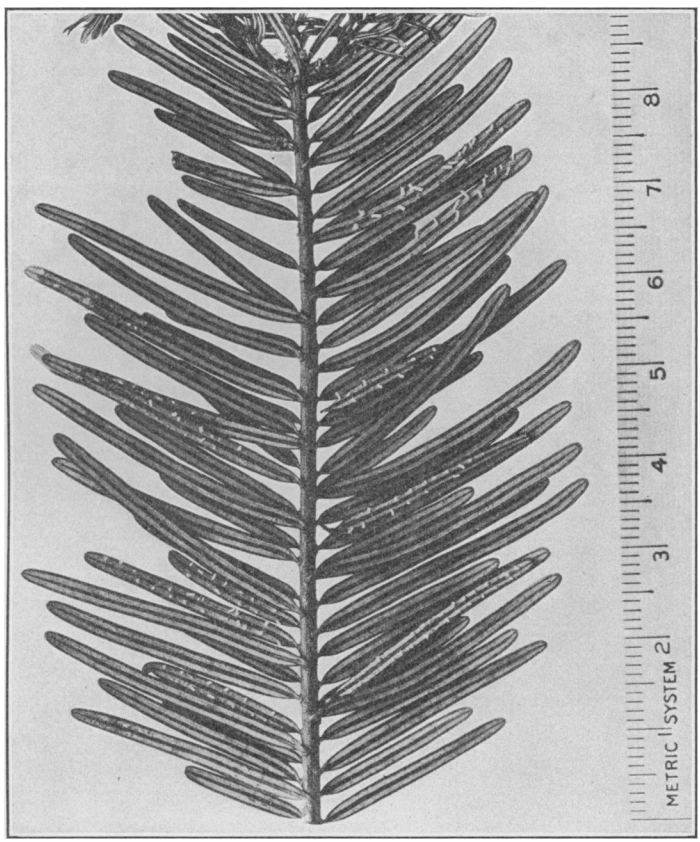

FIG. 1. *Uredinopsis pteridis.* I stage on *Abies grandis* showing appearance upon second year needles.

stage. The infection of these Peridermia is produced in the spring on the youngest needles and the fungi mature the same year. This Peridermium has its alternate stages upon *Pteridium aquilinum pubescens* Underw. (fig. 2) and the conclusion is that the telial stage does not winter over as is the common habit of such rusts. The needles

of the fir must become infected during the same summer or fall in which the telia mature on the fern. Such being the case the advent of lower temperatures prevents the fruiting on the needles until favorable conditions are again present, which is in the early spring of the following year. This is borne out by the collection of the aecial stage fully matured on *Abies grandis* as early as April 12, 1916. This is the earliest collection of any needle rust made in this locality. Other collections were made on April 14, May 2, and June 17, of the same year.

On June 19, 1916, sowings of aeciospores of the above fungus on *Abies grandis* were made on two plants of *Pteridium aquilinum pubescens*. The plants were raised in the greenhouse at Missoula, Mont., from rhizomes dug up in the field on September 4, 1915, and the inoculations were made by the use of celluloid cylinders and cotton plugs. On July 25, 1916, a medium infection of uredinia was found on one of the plants while the other bore no results. The control plants remained normal. A large number (15) of collections of the fungus on *Pteridium aquilinum pubescens* (fig. 2) made throughout Idaho, Washington, and Oregon was always in immediate association with the rust on the needles of Abies. In one particular instance at Lucern Lake, Wash., August 23, 1916, a lake flat was grown up to young *Abies grandis* and the braken fern. The foliage of the latter was completely parasitized by *Uredinopsis pteridis* D. & H. while the needles of the fir were seriously infected with the aecial form of the fungus. No other forest tree rust was present in the vicinity. After a close comparison of the microscopical characters of the above produced uredinial stage with authentic material of *Uredinopsis mirabilis*, *U. osmundae*, *U. struthiopteridis*, *U. atkinsonii*, *U. phegopteridis*, and *U. pteridis*, it was found to coincide with the latter. A careful study of the published descriptions[9] of the species of Uredinopsis in connection with the above culture showed that no great differences existed between *U. copelandi* Sydow and *U. pteridis* other than the hosts. A slight difference in the size of the spores is to be noted. *U. pteridis* has a spore measurement of 11–18 by 30–58 μ and that of *U. copelandi* is 14–18 by 31–40 μ, a difference in length of about 19 μ. This variation is no greater than is found usually occurring in spores of a single species. In comparing the five species of Uredinopsis which have been found to produce an identical aecial stage on *Abies*

[9] Arthur, J. C. Uredinales. N. Amer. Flora 7: 115. 1907.

balsamea, it is found that the spore measurements vary to as great an extent as 19 μ. It was also found that the spores of the above five species bore a similarity in the length and shape of the beaks, these

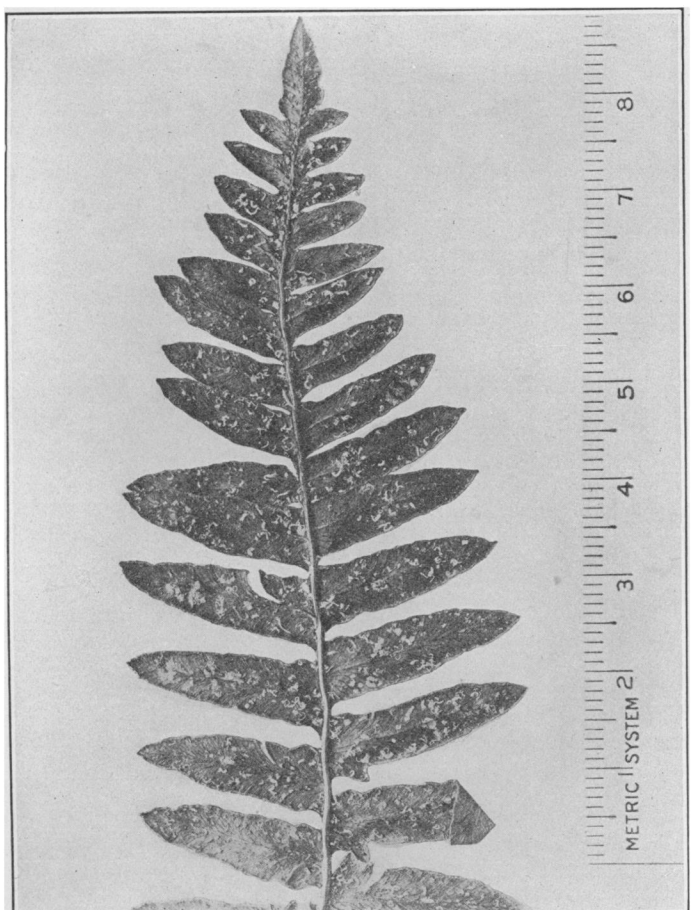

FIG. 2. *Uredinopsis pteridis*. II stage of *Pteridium aquilinum pubescens*. Note the coiled spore masses.

varying in length from 3–10 μ to 12–26 μ with almost similar spore markings. The other two remaining species of Uredinopsis, *U. pteridis* and *U. copelandi*, both have spores with short stout beaks

measuring 3–7 μ long. The spore markings of these two are very similar and are very pronounced when compared to the other five species of the genus. Judging from this it seems that no great reliance in respect to identity of species can be placed upon spore measurements alone.

It is suggested, in view of the above comparison, although cultures are necessary for final determination, that *U. copelandi* be considered identical with *U. pteridis* and placed under the latter species. A technical description of the aecial stage of *U. pteridis* follows:

0. Pycnia not found.

I. Aecia from a limited mycelium appearing on second year needles, hypophyllous, not crowded, forming rows on either side of the midrib, cylindrical, 0.2 to 0.4 mm. across and 1.5 to 2.6 mm. high; peridium colorless, rather delicate, rupturing at apex with fringed margins; cells overlapping, majority rhomboid, (10) 15.0–26.6 by 32.0–43.7 μ, inner walls coarsely and closely verucose, not striate, 8.3 to 10.0 μ thick including tubercles, slightly thicker at one end of cell, outer wall, 6.5 to 7.5 μ thick, smooth; aeciospores mostly globoid, occasionally broadly ellipsoid (50) 13.3–20 by 18.3–24.1 μ, standard (19 by 22 μ), wall colorless, 2 to 2.5 μ thick, coarsely and closely verucose, contents colorless.

On living needles of *Abies grandis* and *A. lasiocarpa* from early spring to late fall depending upon elevation.

The Overwintering of Rusts

It has long been a puzzle as to why the Pucciniastrum occurring on species of Epilobium other than *E. angustifolium* (L.) Scop, has not been found to have its alternate stage upon species of Abies. Successful inoculations of Abies sp. with teliosporic material of *P. pustulatum* on *E. angustifolium* have been made in Europe and in America. Fraser[10] secured results in 1912 upon *Abies balsamea* and has collected the aecia in the field. Check results have been secured by the writers[11] in 1916. All experiments were properly controlled.

The uredinial stage of a Pucciniastrum has often been collected in the northwestern states upon *E. adenocaulon* Haus. but never the telial stage. Examination of available exsiccati material fails to

[10] Fraser, W. P. Cultures of Heteroecious Rusts. Mycologia 4: 175. 1912.

[11] Weir, J. R., and Hubert, E. E. A Successful Inoculation of *Abies lasiocarpa* with *Pucciniastrum pustulatum*. Phytopathology 6: 373. 1916.

disclose any stage of *P. pustulatum* upon *E. adenocaulon* other than the uredinial stage (N. A. U. Nos. 77 and 1087, Fungi Col. Nos. 2575, 2782, 3180, 3773, and 4334, Fungi Dakotensis No. 371, and Jackson's Col. No. 1488). Many collections of the II stage have been made by the writers in months of the year which appear very much out of season for this stage of the rust as the following dates show: March 20, 1916, April 12, 1916, May 4, 1916, June 3 and 15, 1916, July 9, and 14, 1915, August 4 and 20, 1915, September 2, 10, and 28, 1916, October 11, 21, and 28, 1916, November 14, 1916. This indicates a continuation of the uredinial stage throughout the entire year. Examination of all local and acquired collections fails to show where a single collection of the telial stage has been made. On October 18, 1916, three rosettes of *Epilobium adenocaulon* were secured in the field and potted in the greenhouse. Two of the rosettes bore the uredinial stage of *Pucciniastrum pustulatum* on such portions of the leaves as were protected by the outer rosette leaves. All the leaves of the infected rosettes were cut off, care being taken to remove all rusted areas and to cut back the leaves as close to their bases as possible. The only two sources of infection remaining open to the oncoming leaves were the very few urediniospores and the possible mycelium in the portions of the leaves left on the plants. New leaves gradually appeared and on November 1 several of them bore the uredinial stage of the rust. A large number of spores were liberated by these few infections. Germination tests of the spores showed a large percent germinating. A few days later spores were collected which had germinated in situ on the rosettes and produced a small mat of mycelium. Examination of the portions of leaves left on the rosettes after cutting off the infected leaves showed that considerable mycelium was present in the cells of the mesophyll just beneath the epidermis. From November 15 to 22 the rosettes developed a few leaves from two to two and one half inches from the ground, indicating a departure from the strictly rosette habit due to the temperature of the greenhouse. The lowermost ones developed uredinia in abundance. The uppermost leaves as yet showing no infection were sprinkled with urediniospores taken from the pustules beneath on November 18, 1916. On November 27 uredinia developed on the leaves thus inoculated. Two control plants remained normal. The preceding data indicate the presence of a biological species of *P. pustulatum* occurring on *E. adenocaulon* and overwintering by means of mycelium and

uredinia upon the rosettes which continue living until spring. The rust is carried over principally by means of urediniospores which reinfect the leaves of the rosette and continue throughout the year infecting the leaves of the flowering stalk during the spring and summer. The fact that this form of the rust on *E. adenocaulon* produces no telia is evidence of its continuation in the uredinial stage and also explains the absence of a corresponding aecial stage upon Abies.

P. pustulatum occurring upon *E. angustifolium* produces telia which are capable of infecting species of Abies. This plant develops from perennial horizontal root stalks. Rosettes which overwinter are not produced and no evidence has been found to indicate any stage of the rust overwintering on the living plant.

Studies have also been made upon *Coleosporium solidaginis* (Schw.) Thum. occurring upon species of Aster and Solidago.

On October 18 four pots containing rosettes of Aster spp., 2 of *Aster conspicuus* Lindl. and 2 of *A. laevis-gayeri* Grey, infected with the uredinial stage of *C. solidaginis*, were placed in the greenhouse at Missoula, Mont. All of the leaves of the rosettes were removed and the chances for infection depended entirely upon such few urediniospores as had become transferred from the infected leaves. The rust had been mature for some time previous to placing in the greenhouse. On October 28, uredinia appeared on such leaves or portions of leaves as were then present. From this date on other leaves as they appeared became infected and developed scattered groups of uredinia. Four control plants remained normal. Collections of this stage of the rust upon species of Aster and Solidago have been made during the months of the year when only the rosettes of the plants were in evidence. Most of these collections were made in late winter or in early spring before the snow had left the ground. Mains[12] in his article on the overwintering of *Coleosporium solidaginis* produces very good evidence of the overwintering habit of this rust on rosettes of Solidago sp. The collections in Idaho and Montana of infected rosettes of *Solidago missouriensis* Nutt. and *S. canadensis* L. during the months of March and April before the peridia of the aecial stage on *Pinus contorta* have appeared confirms the conclusions of Mains as to the wintering habit of this fungus.

[12] Mains, E. B. The Wintering of *Coleosporium solidaginis*. Phytopathology 6: 371. 1916.

The overwintering of a fungus such as *C. solidaginis* on Aster and Solidago spp. when developing in regions so far removed from the alternate host Pinus as to be too remote for infection by spores carried by the wind is a question which has remained unanswered for some time. Clinton[13] refers to this problem in 1907 and comes to the conclusion that the rust winters over in the rosettes principally by means of the urediniospores. A more recent article by Ludwig[14] gives some very substantial evidence leading to his belief that the uredinial stage of *C. solidaginis* on Aster, Solidago, and other hosts propagates itself through the winter upon the rosettes principally by means of urediniospores. He concludes that the evidence is in favor of the rusts being able to maintain a high degree of vigor for a long period without sexual reproduction.

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[13] Clinton, G. P. Heteroecious Rusts of Connecticut Having a Peridermium for Their Aecial Stage. Report of the Station Botanist **1907**: 369.

[14] Ludwig, C. A. Continuous Rust Propagation without Sexual Reproduction. Proc. Indiana Acad. Sci. **1914**: 219.